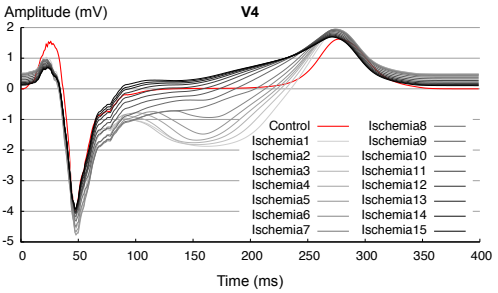
Simulating the Impact of the Transmural Extent of Acute Ischemia on the Electrocardiogram

M Wilhelms, O Dössel, G Seemann

Institute of Biomedical Engineering, Karlsruhe Institute of Technology, Karlsruhe, Germany



ECGs (lead V4) of control case and setups with different transmural extent of ischemia.

During acute cardiac ischemia, electrophysiological properties of the affected tissue are altered. Transmural heterogeneity of the metabolism and the greater distance to the coronary arteries lead to first appearance of the effects in the subendocardium. If the occlusion of the artery worsens, ischemia spreads transmurally towards the subepicardium. Diagnosis of cardiac ischemia is based on the ECG, especially shifts of the ST segment. Computer simulations help understanding the underlying effects and improving the early diagnosis of this pathology. In this work, we simulated the effects of ischemia, which were integrated in a human ventricular cell model, ten minutes after the occlusion of the left anterior descending coronary artery. The heterogeneous ischemic regions were modeled as ellipsoids with varying transmural extent. The excitation propagation was calculated using the monodomain equations in a heterogeneous model of complete ventricles. To obtain the corresponding ECG, the forward problem of electrocardiography was solved. In case of subendocardial ischemia (Ischemia1), small and short action potentials were initiated in the ischemic region causing a transmural gradient of the transmembrane voltage. Therefore, the ST segment was depressed in leads close to the ischemic region. An increase of the transmural extent of the ischemic region (Ischemia11) led to a conduction block in the center. Therefore, the transmembrane voltage exhibited a gradient from the ischemic zone towards the surrounding healthy tissue. Thus, the ST segment was a zero baseline, as in the healthy control case. During transmural ischemia (Ischemia15), the gradient of the transmembrane voltage was concentrated in direction of the ventricular wall leading to ST segment elevation. In this work, we showed that ST segment polarity can be dependent on the transmural extent of the ischemic region.